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Boom Configuration Tests for Calm-Water, Medium-Current Oil Spill Diversion

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BOOM CONFIGURATION TESTS FOR CALM-WATER, MEDIUM-CURRENT OIL SPILL DIVERSION

by

Michael K. Breslin
Mason & Hanger-Silas Mason Co., Inc.
Leonardo, New Jersey 07737

Contract No. 68-03-0490

Project Officer

John S. Farlow
Oil and Hazardous Material Spills Branch
Industrial Environmental Research Laboratory
Edison, New Jersey 08817

INDUSTRIAL ENVIRONMENTAL RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
CINCINNATI, OHIO 45268

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FOREWORD

When energy and material resources are extracted, processed, converted, and used, the related pollutional impacts on our environment and even on our health often require that new and increasingly more efficient pollution control methods be used. The Industrial Environmental Research Laboratory - Cincinnati (IERL-Ci) assists in developing and demonstrating new and improved methodologies that will meet these needs both efficiently and economically.

This report describes the performance of various deployment configurations of standard booms in medium-current inland streams. The more promising ones indicate that a considerable improvement in performance can be achieved with relatively little additional effort. These techniques will be of interest to all those interested in cleaning up oil spills in coastal and inland waters. Further information may be obtained through the Resource Extraction and Handling Division, Oil and Hazardous Materials Spills Branch, Edison, New Jersey.

David G. Stephan
Director
Industrial Environmental Research Laboratory
Cincinnati

ABSTRACT

The purpose of this test program was to determine the effects of boom angle, length, and rigging configuration on diversion of oil floating on moving streams.

The B.F. Goodrich Seaboom was chosen for the program because of its availability, durability, and stability. It was rigged in different diversionary modes and towed into an oil slick at the U.S. Environmental Protection Agency's (USEPA) Oil and Hazardous Materials Simulated Environmental Test Tank (OHMSETT) test facility at various speeds, until critical stability speed was attained. Boom performance was recorded on photographs, video tapes, and observer notes. Results were evaluated in terms of the percentage of oil lost beneath the boom and away from the rear of the boom. A "nozzle-shaped" boom configuration achieved the best diversion at tow speeds examined above 1.0 m/s. Different exits from the nozzle configuration were investigated to find which one released the oil with the least amount of entrainment and spreading. A straight exit with tapered ends worked best. Tests were conducted in accordance with a test matrix developed by the U.S. Environmental Protection Agency.

This report was submitted in fulfillment of Contract No. 68-03-0490, Job Order No. 33, by Mason & Hanger-Silas Mason Co., Inc., Leonardo, New Jersey, under the sponsorship of the U.S. Environmental Protection Agency. This report covers a period from March 28 to April 5, 1977; from April 11 to April 15, 1977; and from September 23 to September 30, 1977, when the work was completed.

CONTENTS

Foreword iii
Abstract iv
Figures vi
Tables vii
Abbreviations and Symbols viii
List of Conversions ix
Acknowledgment x

1 Introduction and Objectives 1
2 Conclusions and Recommendations 2
3 Test Apparatus Description 4
4 Test Plan and Procedures 8
5 Discussion of Results 21

References 32
Appendices

A. Facility Description 33
B. Diversionary Boom Length vs. Angle Comparison 35

FIGURES

Number		Page
1	Nozzle configuration showing main bridge tow points and oil distribution points	4
2	Exit of 20° "V" configuration showing auxiliary bridge tow points	5
3	Tow back device attached to trailing end of diversionary boom	5
4	General test set-up and personnel placement during testing	9
5	Test set-up for 32° single diversionary boom	10
6	Test set-up for 20° single diversionary boom	11
7	Test set-up for 20° double diversionary or "V" boom configuration	12
8	Test set-up for the parabolic boom nozzle configuration	13
9	Test set-up for "belled" exit nozzle boom configuration	14
10	Test set-up for constricted throat and "belled" exit nozzle configuration	15
11	Test set-up for the parabolic nozzle configuration with the straight, lifted exit	16
12	Test set-up for parabolic nozzle configuration with parabolic exit	17
13	Test set-up for parabolic nozzle configuration with quarter-circle exit	18
14	Design of parabolic nozzle configuration	20
15	Performance of B.F. Goodrich 18 PFX boom (32° angle, diversionary mode 28.5 m long)	22
16	Performance of B.F. Goodrich 18 PFX boom (20° angle, diversionary mode 21.4 m long)	23
17	Performance of B.F. Goodrich 18 PFX boom (20° "V" configuration, 14.3 m on each side)	..
18	Performance of B.F. Goodrich 18 PFX boom (parabolic nozzle configuration, 14.3 m on each side)	2.

TABLES

Number		Page
1	Single Diversionary Boom Test Results	26
2	Double Diversionary Boom ("V") Test Results	28
3	Double Diversionary (Nozzle) Boom Test Results	29

ABBREVIATIONS AND SYMBOLS

ABBREVIATIONS

C	--Centigrade
cm	--centimetre
deg	--degree
F	--Fahrenheit
kg	--kilogram
m	--metre
min	--minute
mm	--millimetre
N	--Newton
s	--second

SYMBOLS

°	--degree
Θ	--angle between boom and centerline of tank
%	--percent
x	--distance from boom exit parallel to the centerline of tank
y	--distance from centerline of boom
dy/dx	--slope of parabolic boom

LIST OF CONVERSIONS

METRIC TO ENGLISH

To convert from	to	Multiply by
Celsius	degree Fahrenheit	$t_C = (t_F-32)/1.8$
joule	erg	1.000 E+07
joule	foot-pound-force	7.374 E-01
kilogram	pound-mass (lbm avoir)	2.205 E+00
metre	foot	3.281 E+00
metre	inch	3.937 E+01
$metre^2$	$foot^2$	1.076 E+01
$metre^2$	$inch^2$	1.549 E+03
$metre^3$	gallon (U.S. liquid)	2.642 E+02
$metre^3$	litre	1.000 E+03
metre/second	foot/minute	1.969 E+02
metre/second	knot	1.944 E+00
$metre^2$/second	centistoke	1.000 E+06
$metre^3$/second	$foot^3$/minute	2.119 E+03
$metre^3$/second	gallon (U.S. liquid)/minute	1.587 E+04
newton	pound-force (lbf avoir)	2.248 E-01
watt	horsepower (550 ft lbf/s)	1.341 E-03

ENGLISH TO METRIC

centistoke	$metre^2$/second	1.000 E-06
degree Fahrenheit	Celsius	$t_C = (t_F-32)/1.8$
erg	joule	1.000 E-07
foot	metre	3.048 E-01
$foot^2$	$metre^2$	9.290 E-02
foot/minute	metre/second	5.080 E-03
$foot^3$/minute	$metre^3$/second	4.719 E-04
foot-pound-force	joule	1.356 E+00
gallon (U.S. liquid)	$metre^3$	3.785 E-03
gallon (U.S. liquid)/ minute	$metre^3$/second	6.309 E-05
horsepower (550 ft lbf/s)	watt	7.457 E+02
inch	metre	2.540 E-02
$inch^2$	$metre^2$	6.452 E-04
knot (international)	metre/second	5.144 E-01
litre	$metre^3$	1.000 E-03
pound-force (lbf avoir)	newton	4.448 E+00
pound-mass (lbm avoir)	kilogram	4.535 E-01

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SECTION 1

INTRODUCTION AND OBJECTIVES

Oils to meet our growing energy and lubrication needs are being handled in increasing amounts and variety. The potential for accidental discharge of these materials poses a serious threat to the welfare of the general public and the environment. Since such spills are not likely to cease (1), effective methods for dealing with oil spills must be developed. Such is the purpose of these tests conducted at the U.S. Environmental Protection Agency's (USEPA) Oil and Hazardous Materials Simulated Environmental Test Tank (OHMSETT). See Appendix A.

Satisfactory diversion, containment, and cleanup of oil spills is still in the development stages even on calm, inland waters. Because of the relative inexperience of many people engaged in oil spill reponse, the effective use of booms and certain limits of their capability and rigging must be determined and publicized. Accordingly, these tests were designed to find the most effective use of conventional flat-plate booms (usually, the only kind available) in spill situations where the water current exceeds 0.5 m/s. In streams the current speed generally increases with distance from shore; if a boom can be rigged so as to move the oil into a confined area in a low current region, the spill can then be picked up by conventional means. If a high current skimming device is available, the boom could also be used to concentrate the oil in front of the device.

This USEPA test program was undertaken to obtain vital data needed to begin standardization of boom use in medium current situations and to lay the groundwork for further innovative study.

SECTION 2

CONCLUSIONS AND RECOMMENDATIONS

The boom configurations described here were rigged with the boom at rest with respect to the OHMSETT tank water. The boom was then towed through the tank water to simulate a current. In the field, the boom must be rigged in a current, a more difficult situation. Any field use of the boom configurations shown in this report will go far more smoothly if they can be planned and practiced before an oil spill occurs.

If a straight diversionary boom is used to divert oil, parachute mooring lines are necessary. The lines should be of small diameter to avoid generating standing waves and thus entraining oil. Small cusps form in the boom at the points of attachment and cause some shedding, but not as much as the drastic cusp at the trailing end of a boom without parachute lines. The lines also stabilize the boom, and permit higher speeds before stability failure (e.g., boom diving or planing) occurs.

The angle of the boom to the current directly affects performance. The more perpendicular to the current the boom stands, the lower the speed at which oil loss and boom stability failure occur. When the perpendicular component of current against a diversionary boom approaches 0.51 m/s, oil shedding increases dramatically.

Few vortices formed along the boom skirt in any configuration. Oil losses were predominantly due to the shearing action of the water on the oil/water interface (shedding). Not all of the oil which passed beneath the boom skirt was lost. The horizontal vortical action of the water passing beneath the skirt drew much of the entrained oil into a quiescent zone behind the boom. The same vortical action kept the oil from leaving the rear of the boom. The result was that the oil traveled down behind the boom and rejoined the unentrained oil at the exit.

The straight exit from the nozzle configuration, with the rear of the boom sections lifted from the water, proved to be the best shape of those tested. The exiting oil slick remained the width of the exit for about ten seconds before beginning to spread. Entrainment was minimal due to the absence of turns or sharp edges that would have caused turbulence. Even with the boom skirt tied up around the floatation, the parabolic and quarter-circle exits created too much turbulence for the oil to leave the boom without clinging to the floatation or being entrained.

Oil losses increased downstream along the boom when a straight diversionary configuration was used. Nozzle-shaped configurations appear promising since less entrainment and fewer standing vortices resulted at the exit. At 1.67 m/s, the nozzle configuration lost only 7% of the encountered oil, while the 20° "V" configuration lost 15%.

The crucial area of the nozzle shape is the leading portion of the booms. The angle at which the booms at the nozzle mouth engages the water must not be too large, or turbulence which would drive the oil downward might result. During the higher tow speed tests, the strong horizontal vortices generated at the leading portions of the booms were felt further downstream and instigated oil loss. Boom stability failure at low current velocities (0.75 m/s) could also result from too great an attack angle.

Observation and photo/video documentation of tests using oil are vivid and to the point. The use of hot film anemometry at OHMSETT has proven very delicate and time-consuming in boom study. Problems inherent with large-scale testing also produce problems in probe placement and protection. However, small-scale testing using hot film probes and streamers could be helpful. Systematic variation of boom skirt depth and position might delineate areas where oil could be contained behind the boom, as well as in front.

SECTION 3

TEST APPARATUS DESCRIPTION

BOOM AND RIGGING DESCRIPTION

The B.F. Goodrich 18 PFX Seaboom was used for these tests. Design characteristics are listed below. Four boom sections were painted and marked in metres to allow unambiguous topside and underwater reference for photographic, video, and observer documentation. The booms were rigged in the desired configuration with the leading ends attached to tow points on the main bridge (Figure 1).

Figure 1. Nozzle configuration showing main bridge tow points and oil distribution points.

The trailing ends of the boom were either attached to tow points on the auxiliary bridge (Figure 2), tied to a tow-back device (Figure 3), or held by ropes to the bridges. The tow-back device was clamped to the bridge drive cable and rode along the tank wall when the bridge moved.

Figure 2. Exit of 20° "V" configuration showing auxiliary bridge tow points.

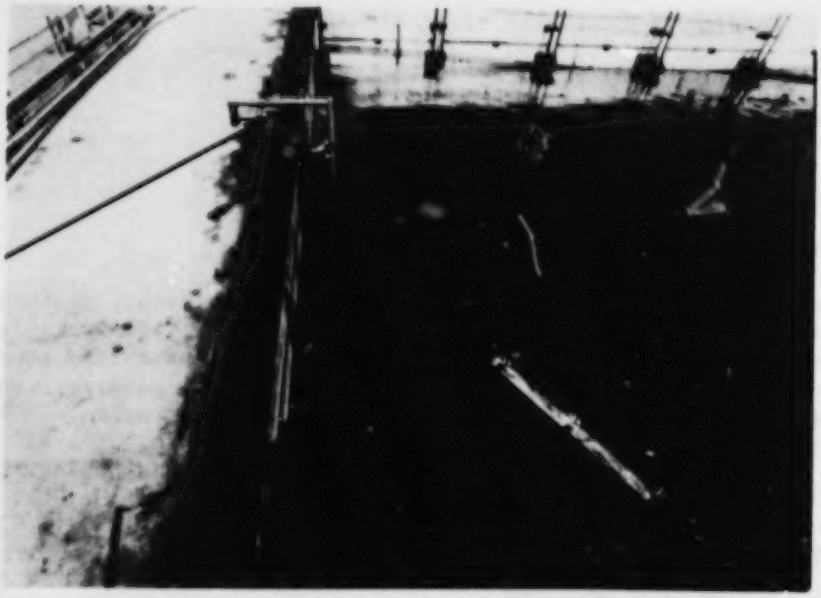


Figure 3. Tow back device attached to trailing end of diversionary boom.

This moveable tow point permitted the boom to be tensioned during tests and returned to the tank's north end starting point after each test run. Parachute lines, 1.27 cm in diameter, were attached to the boom floatation both at the boom section junctions and at intermediate points to maintain the nozzle configurations. A spreader bar was used where a venturi effect tended to collapse the two sides of the configuration into each other. Each spreader bar consisted of a piece of lightweight aluminum tubing with a tie line slipped through and tied off at each end to the boom floatation. The oil slick was distributed uniformly onto the water surface ahead of the boom over the entire projected sweep width. Tests performed with the parabolic and quarter-circle exit configurations had the skirt of the boom tied up out of the water to reduce turbulence (i.e.-- only the floatation had an effect upon the oil in the exit portion).

Design Characteristics

1. Draft--0.30 m
2. Freeboard--0.15 m
3. Floatation--continuous chambers of closed cell foam, protected by 0.635 cm coating of polyvinyl chloride and secured at the ends with wooden plugs
4. Ballast--tubular extrusion, filled with lead shot and sand
5. Skirt material--0.635 cm thick vinyl sheet reinforced with rib handles of urethane
6. Tension member--self tensioning boom
7. Weight--11.01 kg/m
8. Excess buoyancy--10.42 kg/m
9. Standard section length--7.16 m

VIDEO AND PHOTOGRAPHIC DOCUMENTATION

Cameras provided visual documentation of test layout, equipment, and performance characteristics. A black and white TV camera in a waterproof case provided underwater video coverage, which was recorded on 2.54-cm video tape. Topside and tank-side window, coverage was provided by two 16-mm movie cameras and a 35 mm still camera. A 1.8 x 1.8-m mirror and frame was positioned on the tank bottom at a 45° angle to provide a vertical underwater view of the boom when shooting through the window.

TEST FLUID DESCRIPTION

Circo (Sun Oil Company brand name, Philadelphia, Pennsylvania) medium

oil was used in all tests. The specifications of the oil were as follows:

Specific Gravity	0.921
Viscosity	190×10^{-6} m^2/s @ 22.7°C
Interfacial Tension*	19.2×10^{-3} N/m @ 22.7°C
Surface Tension*	35.3×10^{-3} N/m @ 22.7°C
% Water and Sediment	0

*Tested with OHMSETT tank water (16 ppt salinity)

This oil approximated the characteristics of one of those recommended in American Society for Testing and Materials (ASTM) Committee F-20's proposed standard for testing advancing oil skimmers.

SECTION 4

TEST PLAN AND PROCEDURE

TEST RATIONALE

The use of dyed oil was found to be the best method for determining boom performance. Earlier studies of boom hydrodynamics (2, 3) performed at the USEPA OHMSETT facility incorporated hot film anemometry, dyed water streams, and dyed oil to observe and record flow phenomena around a boom. However, the tow speeds were all equal to or less than 1.07 m/s and only one boom configuration (one-sided diversionary) was investigated. The current series of tests initially used hot-film probe analysis of the turbulence around the oil boom and streamers attached to the boom or towed in front of it from a vertical staff to observe flow patterns. The boom was rigged in the straight, single diversionary mode, and the hot-film probe was positioned as closely behind the skirt as possible. Since the boom and tow lines stretched under tow, such placement could have been hazardous to the probe. Because of the time required for placement, calibration, and troubleshooting, use of the probe was terminated. The streamers (colored yarn) were observable in various locations along the boom and at different lengths, depths and tow speeds. However, oil loss mechanisms and quantities could not be adequately determined. The use of streamers was later discontinued in favor of dyed oil.

The series of dyed oil experiments began with the boom rigged in the single boom diversionary mode (Figure 4). Oil was distributed evenly over the sweep width of the boom as it was towed southward. Underwater video and photography recorded the failure points along the boom. The boom tow speed was kept constant during a single pass down the tank. After each run the oil was skimmed back to the north end of the tank, and the next test was run at a higher tow speed. Following the test run where oil loss was excessive because of high tow speed, the boom configuration was changed and the tests of that new configuration were begun. The boom configurations, in order of testing, included 32° diversionary (Figure 5), 20° diversionary (Figure 6), 20° "V" (Figure 7) and parabolic nozzle (Figure 8). "Belled" exit nozzle (Figure 9) and constricted throat with "belled" exit nozzle (Figure 10) configurations were tested at the end of the test series (ending April 15, 1977) to try to reduce the eddy current and entrainment of oil left by the passing boom. The last test series (ending September 30, 1977) involved adding another boom section to each side of the nozzle configuration and rigging them to form a straight exit (Figure 11), a parabolic exit (Figure 12) and a quarter-circle exit (Figure 13).

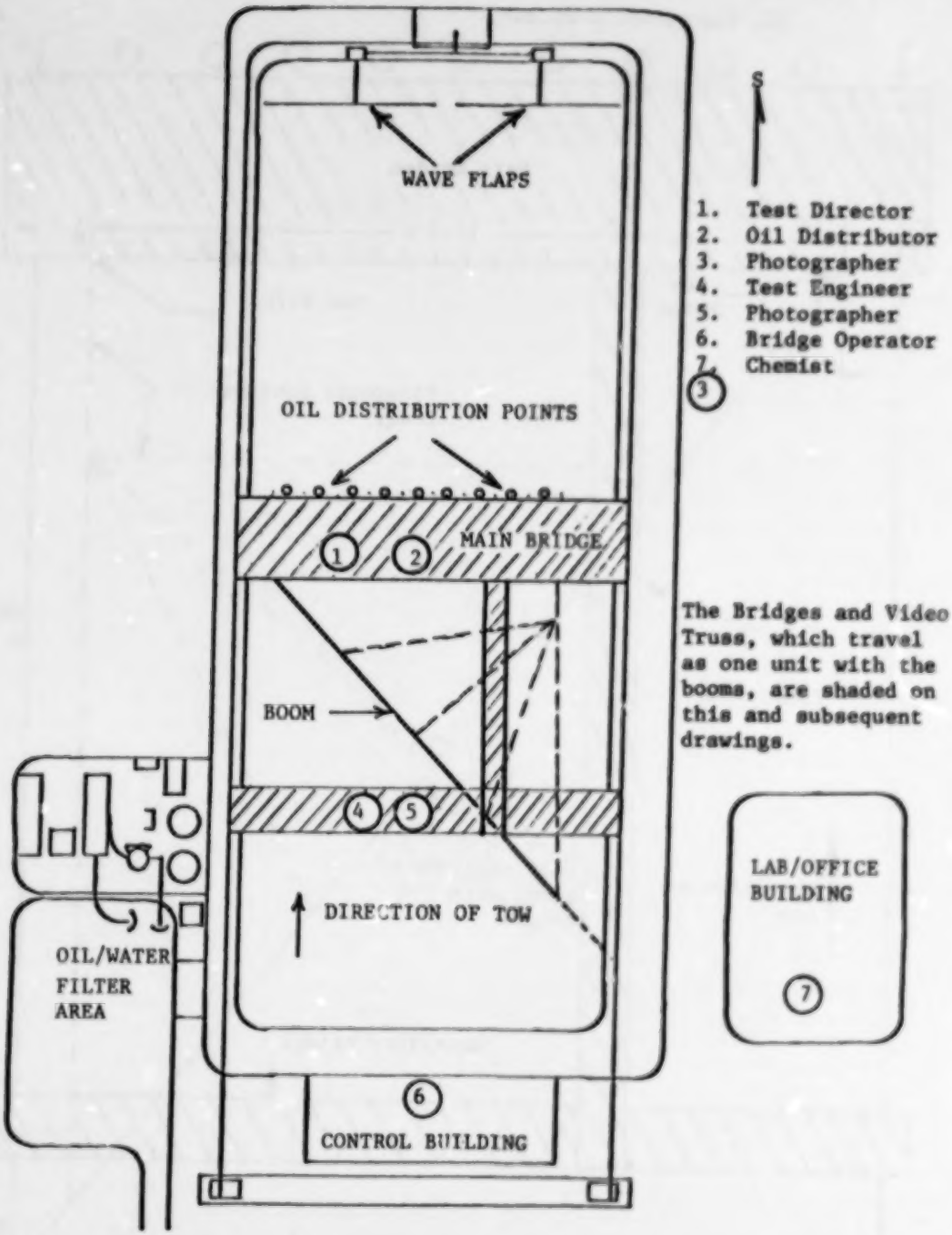


Figure 4. General test set-up and personnel placement during testing.

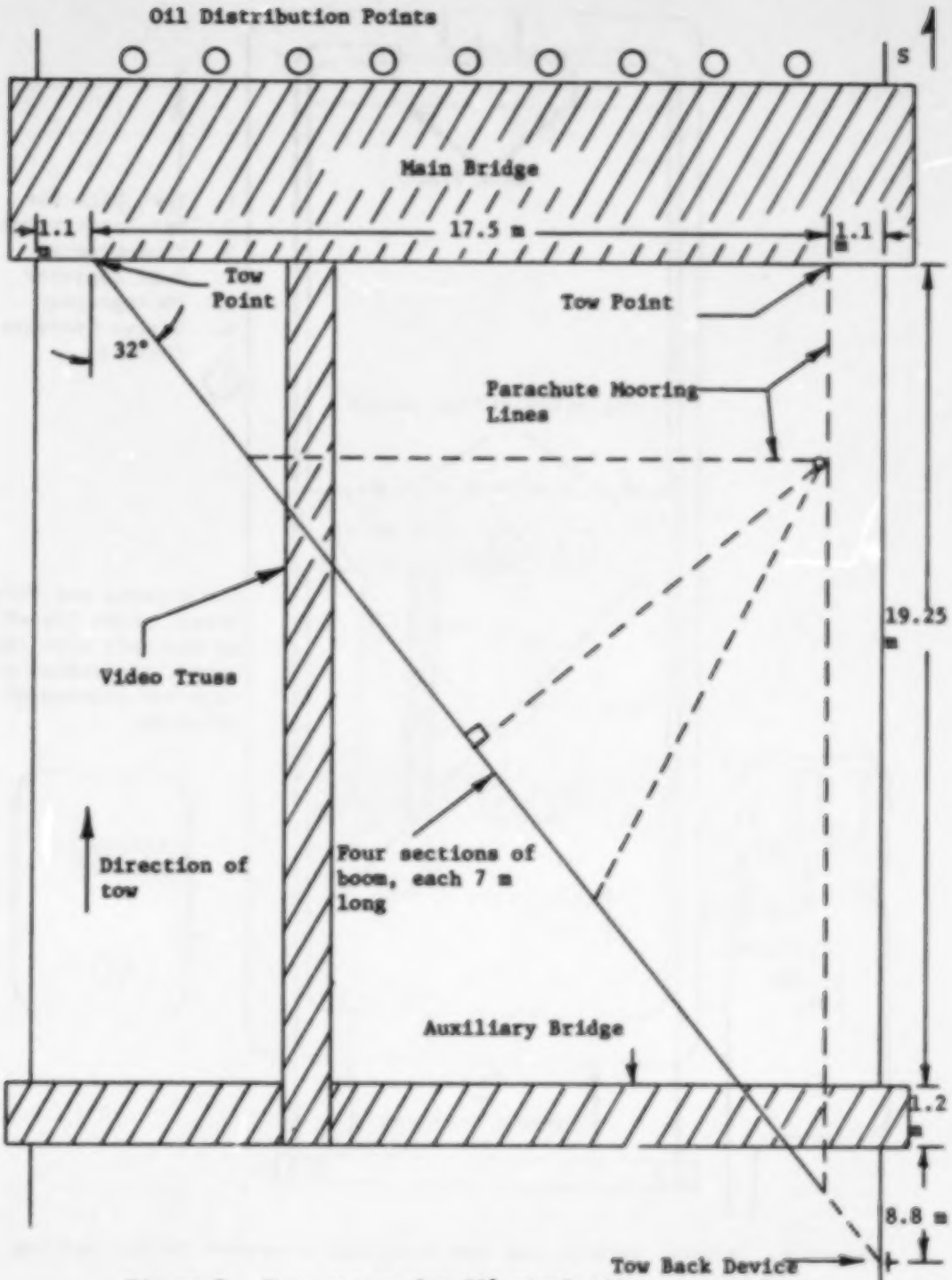


Figure 5. Test set-up for 32° single diversionary boom.

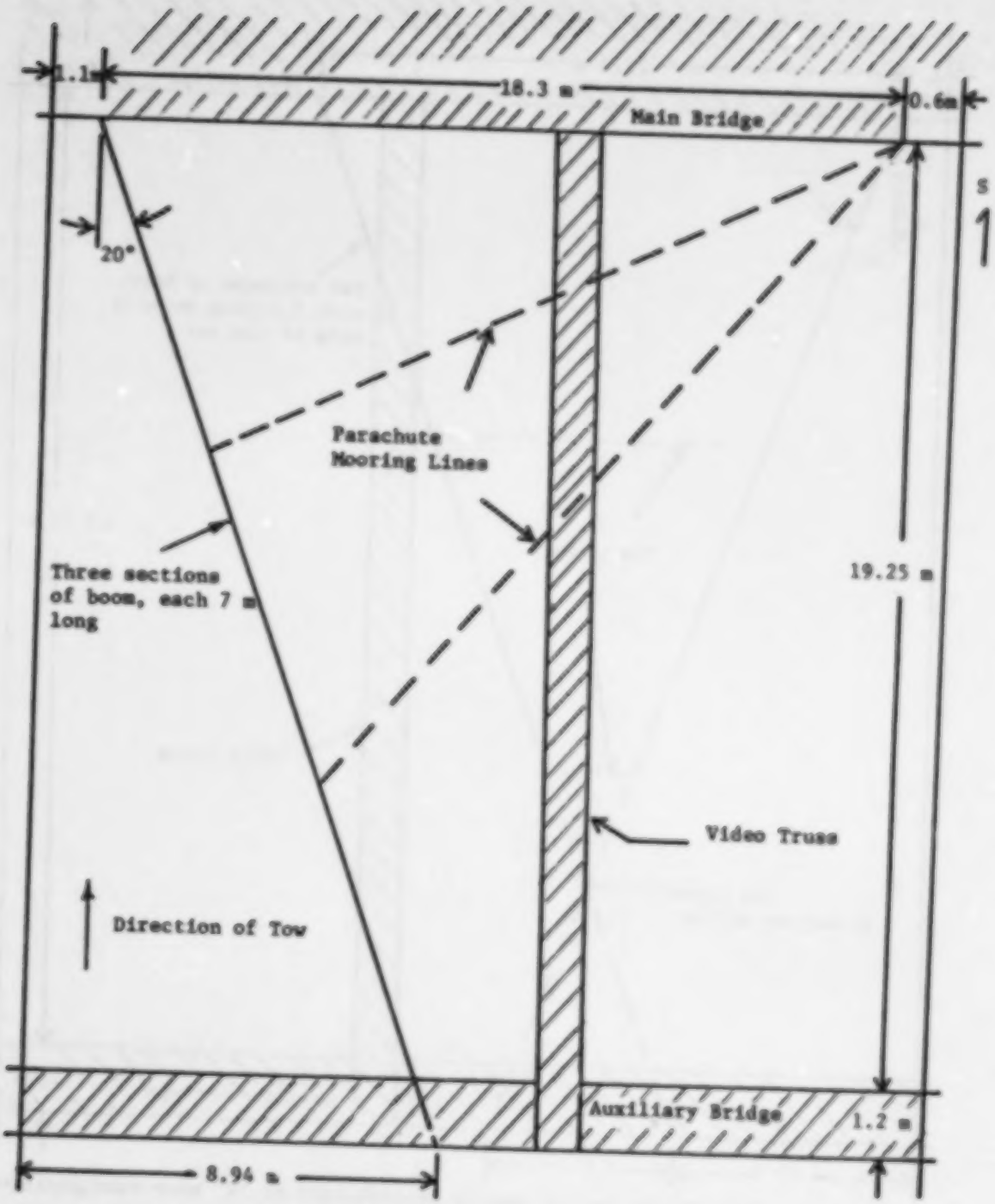


Figure 6. Test set-up for 20° single diversionary boom.

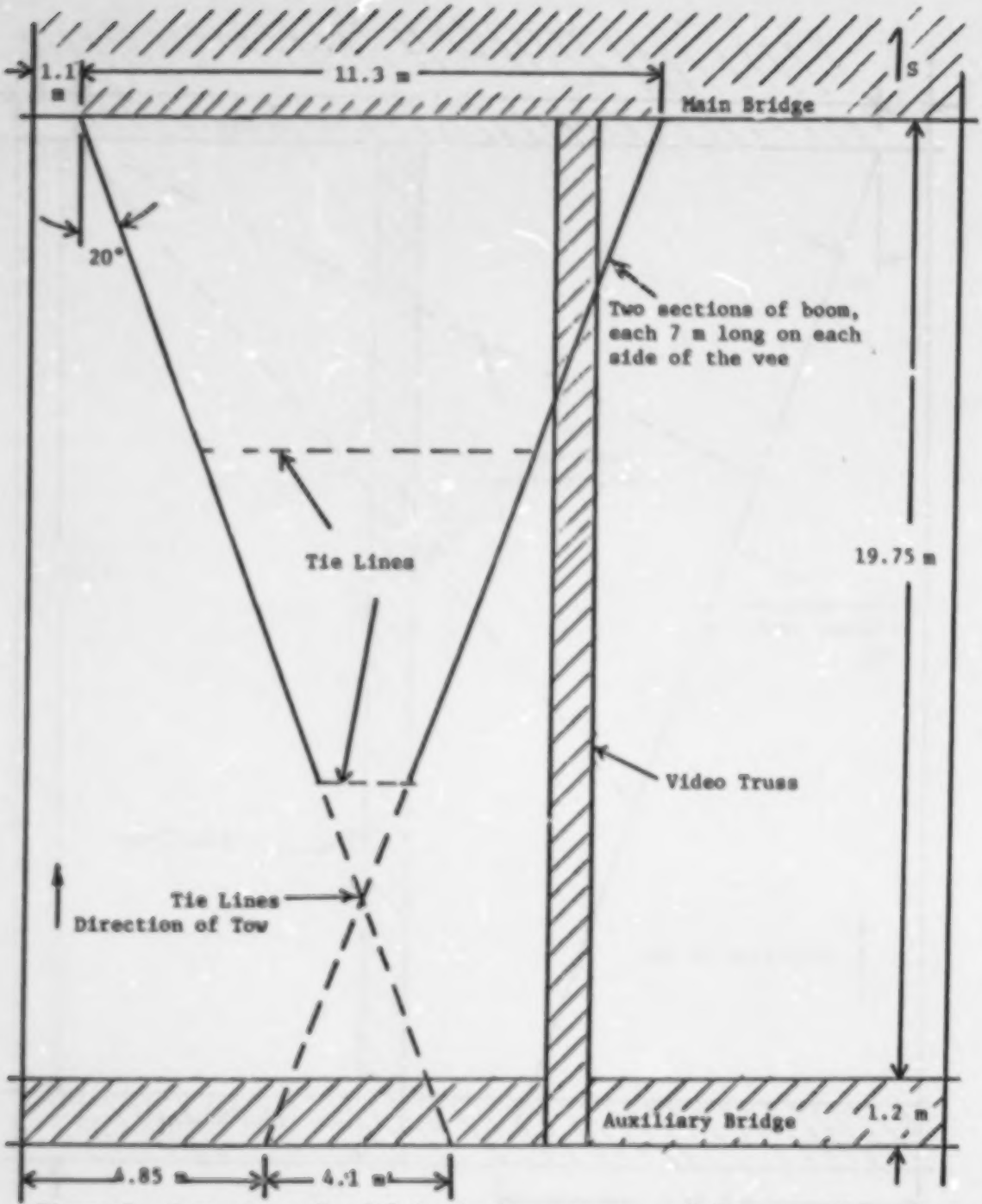


Figure 7. Test set-up for 20° double diversionary or "V" boom configuration.

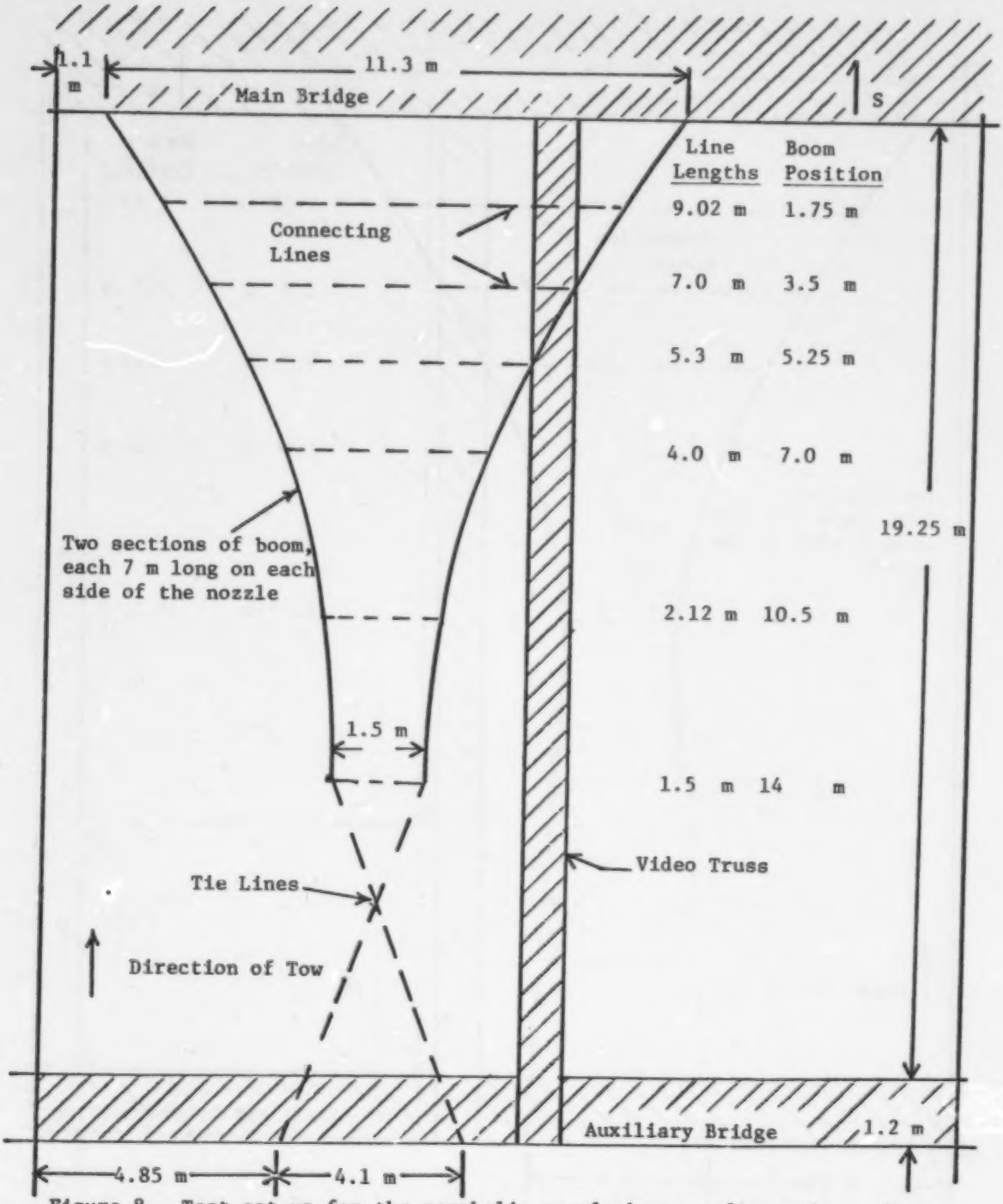


Figure 8. Test set-up for the parabolic nozzle boom configuration. (Compare with Figure 1).

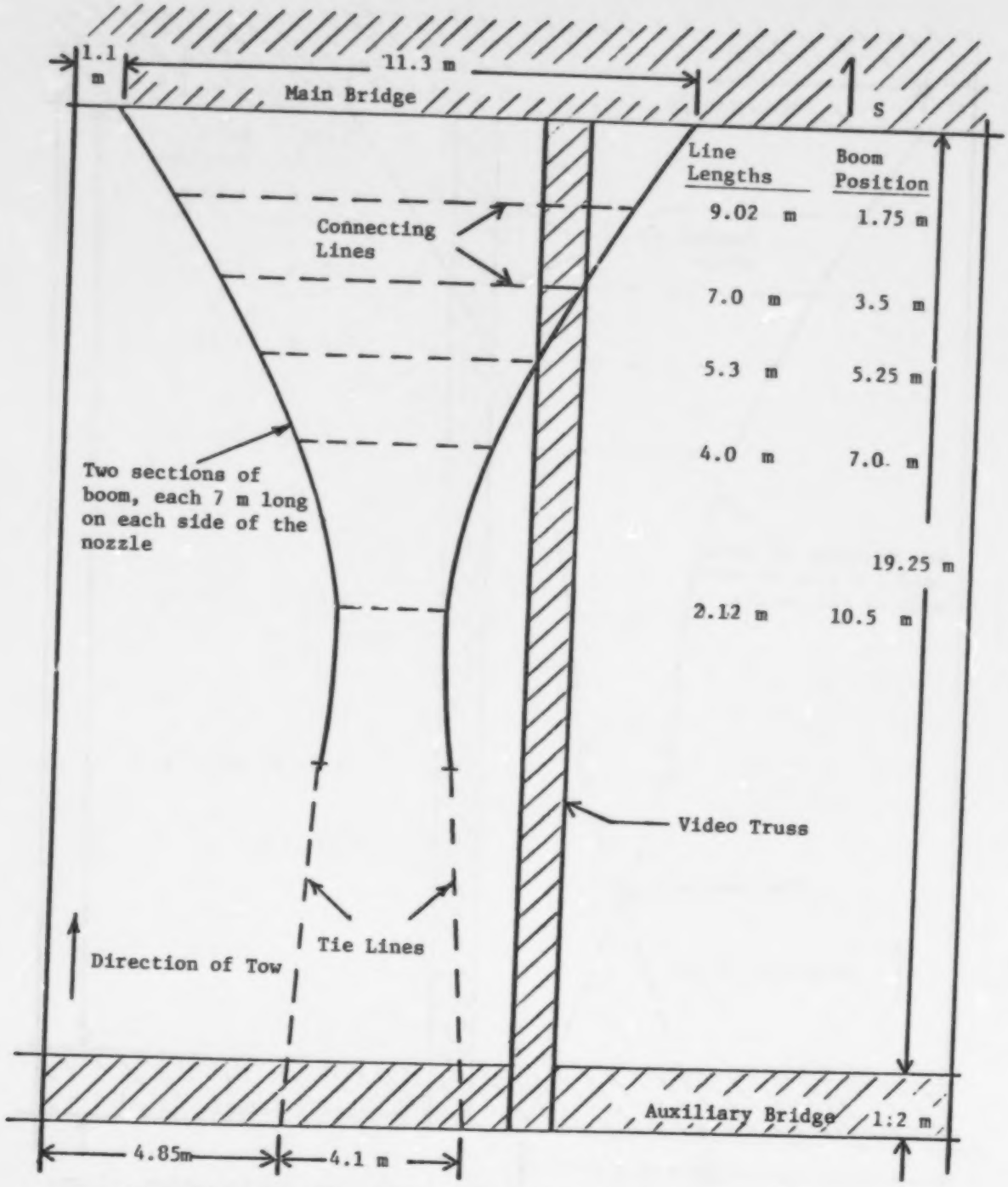


Figure 9. Test set-up for "belled" exit nozzle boom configuration.

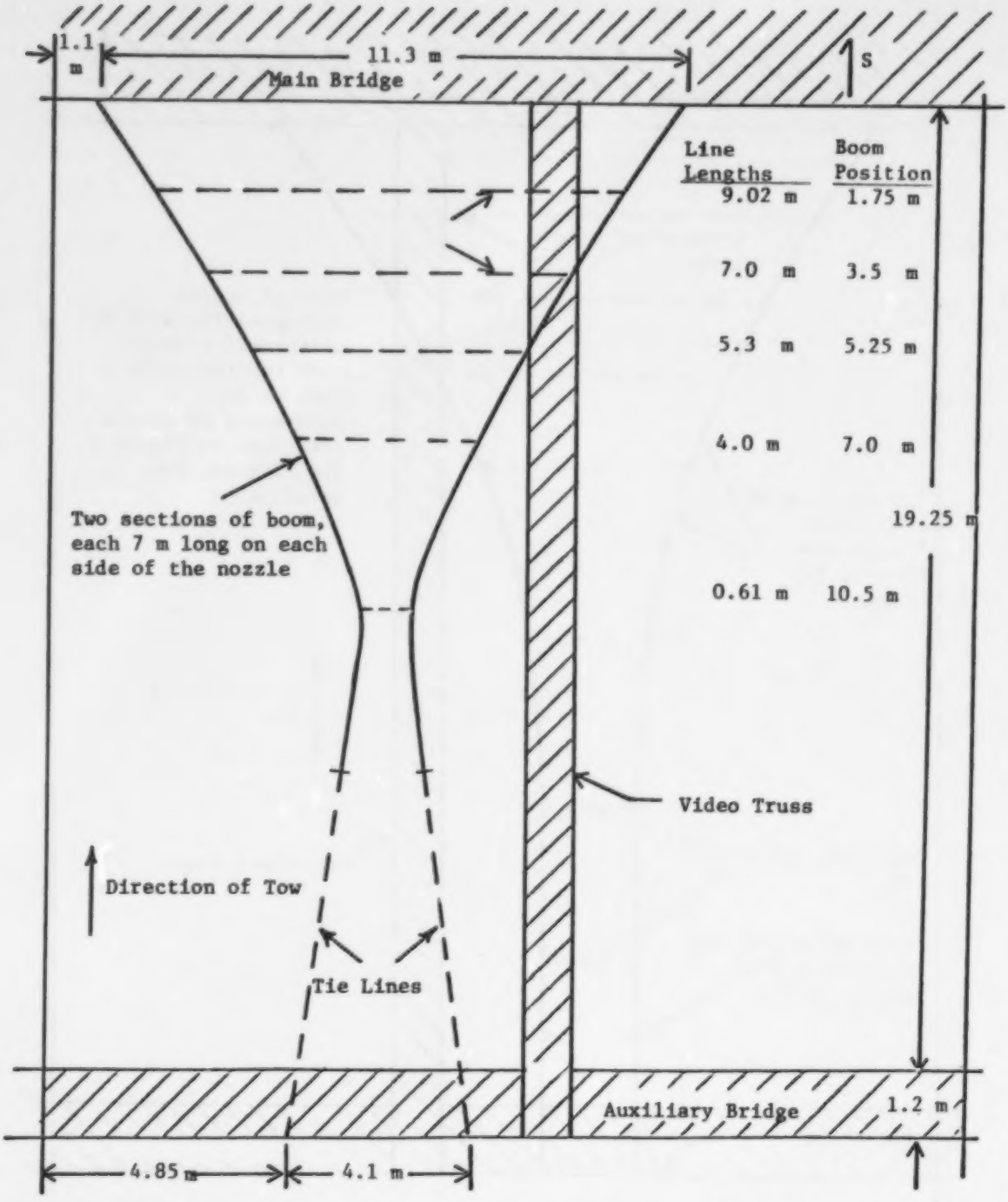


Figure 10. Test set-up for constricted throat and "belled" exit nozzle configuration.

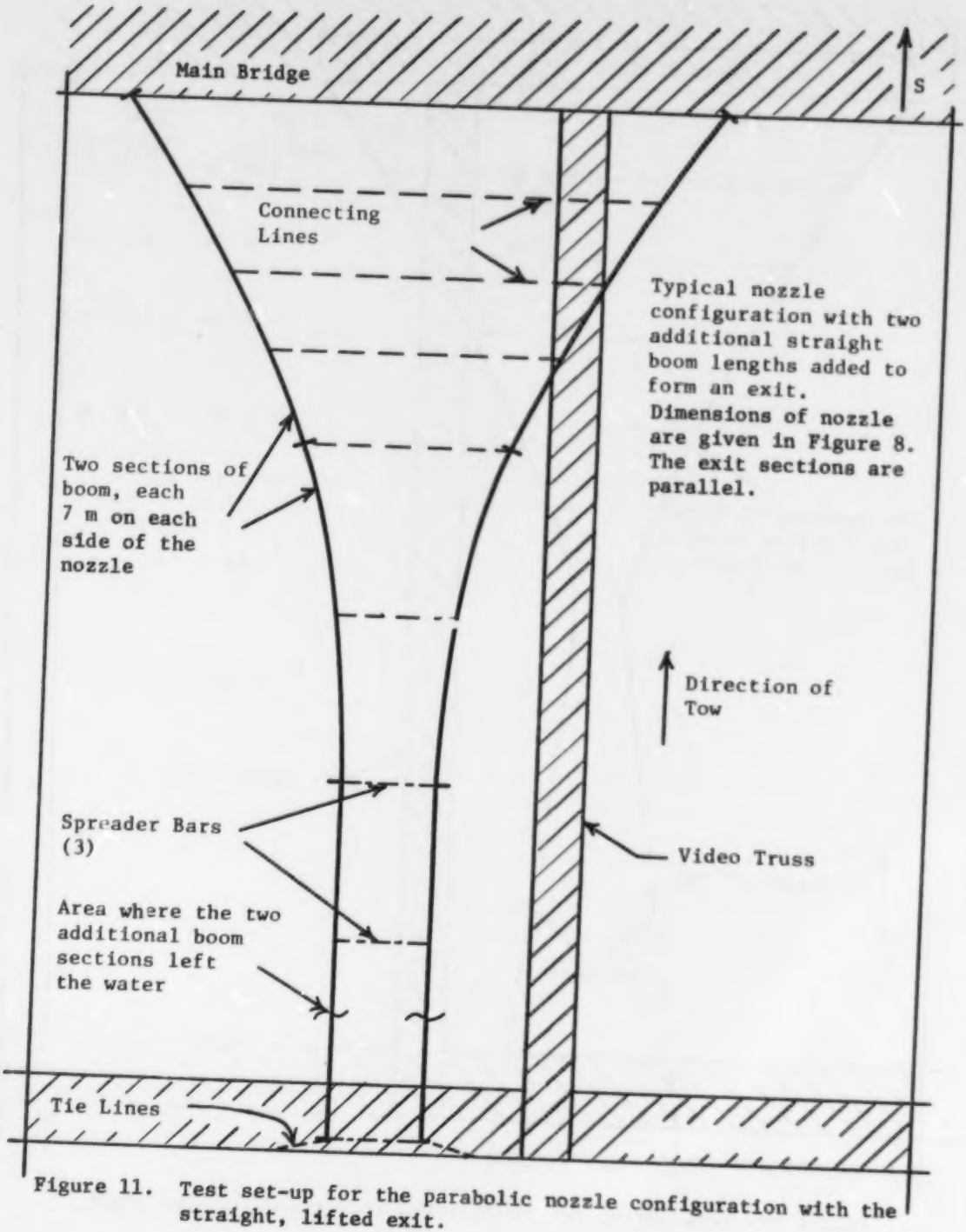

Main Bridge
S
Connecting Lines
Typical nozzle configuration with two additional straight boom lengths added to form an exit. Dimensions of nozzle are given in Figure 8. The exit sections are parallel.
Two sections of boom, each 7 m on each side of the nozzle
Direction of Tow
Spreader Bars (3)
Video Truss
Area where the two additional boom sections left the water
Tie Lines

Figure 11. Test set-up for the parabolic nozzle configuration with the straight, lifted exit.

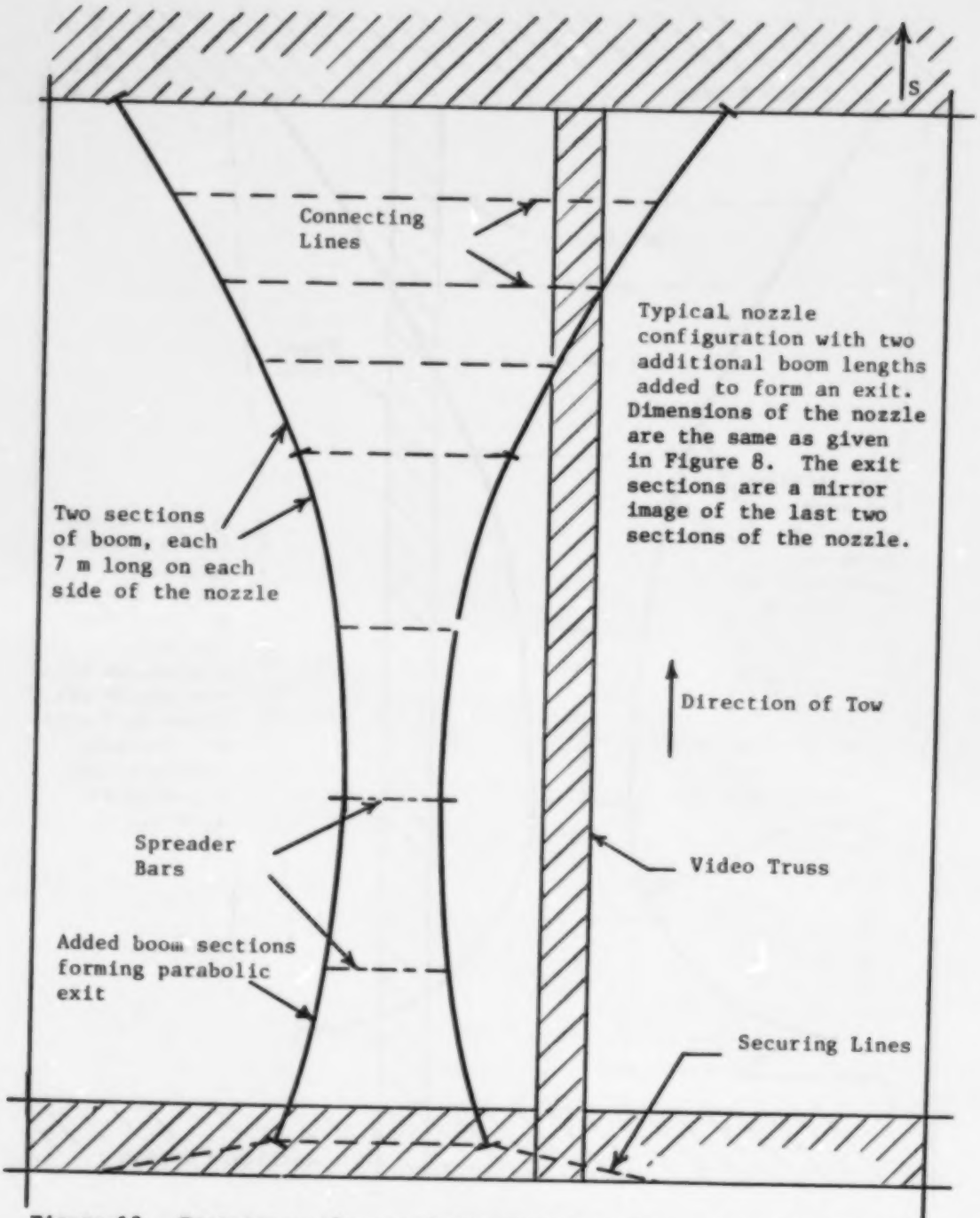

S
Connecting Lines
Typical nozzle configuration with two additional boom lengths added to form an exit. Dimensions of the nozzle are the same as given in Figure 8. The exit sections are a mirror image of the last two sections of the nozzle.
Two sections of boom, each 7 m long on each side of the nozzle
Direction of Tow
Spreader Bars
Video Truss
Added boom sections forming parabolic exit
Securing Lines

Figure 12. Test set-up for parabolic nozzle configuration with parabolic exit.

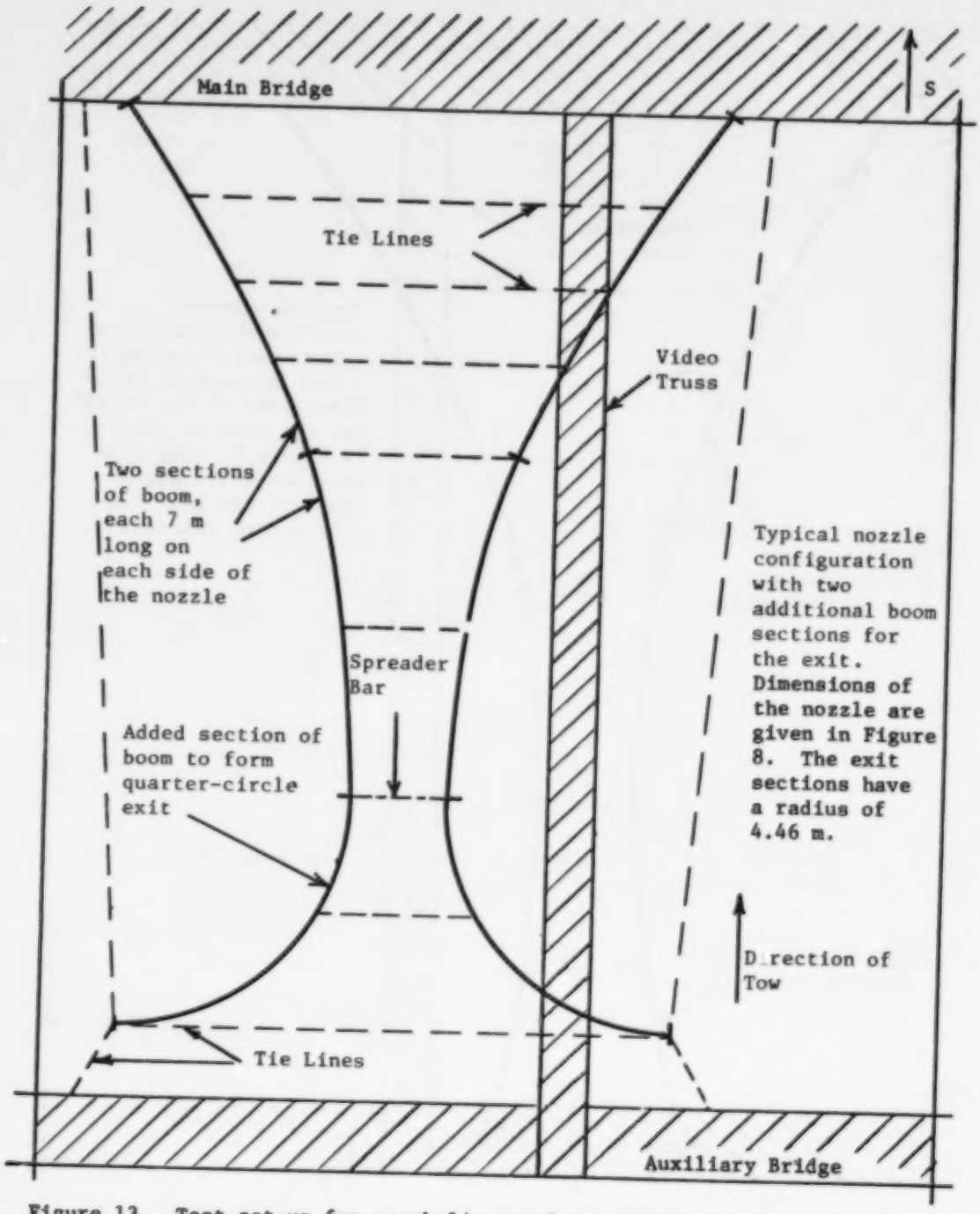


Figure 13. Test set-up for parabolic nozzle configuration with quarter-circle exit.

A basic parabolic contour was chosen for the nozzle configuration (Figure 14). This gave an easily reproducible form with which the investigation of special boom configurations could begin. Cross section shapes of gas nozzles could only be used as a guide due to the difference in compressibilities between air and water. The specific distances between the booms were calculated from the equation shown with the drawing. This equation was derived on the basis that the sweep width and discharge opening being identical with the 20° double diversionary "V" configuration.

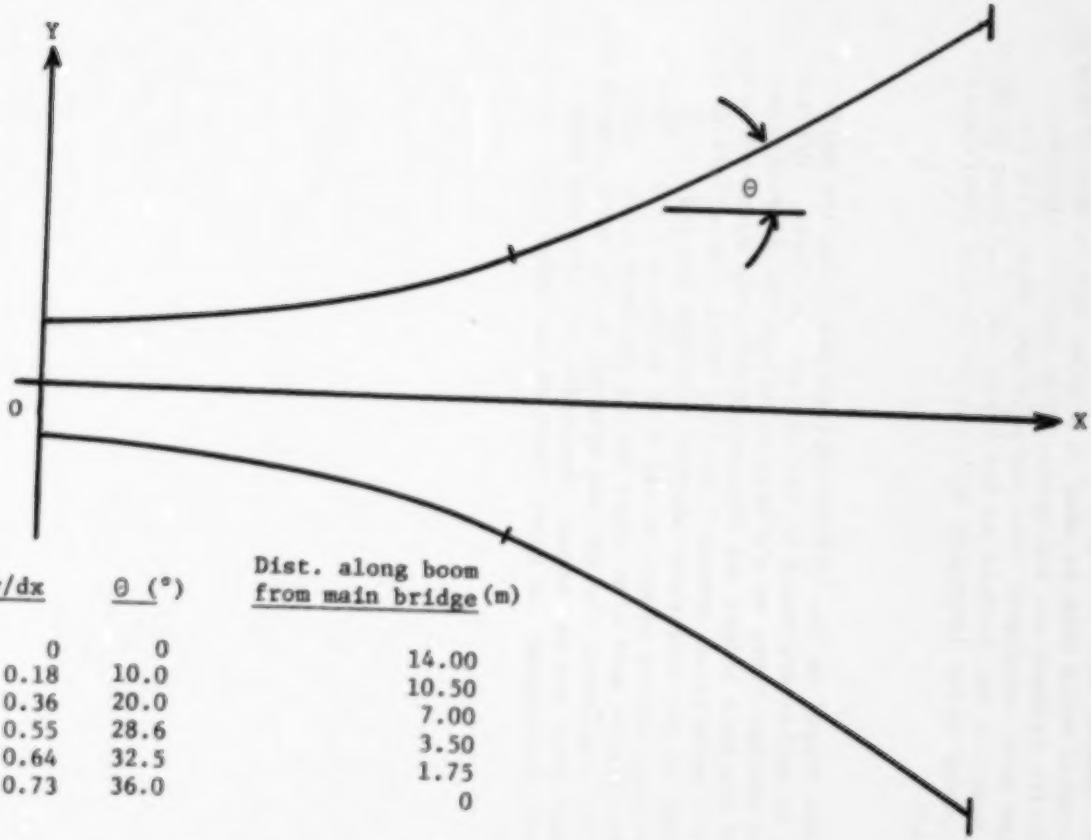
PROCEDURES

The boom was rigged in the desired configuration and the main bridge was set in motion southward at the correct tow speed. Oil was pumped from the storage tanks on the main bridge to the distribution points ahead of the main bridge and discharged onto the water surface. The oil slick was maintained between 1 to 2 mm thick. Observers on the moving bridge and at the underwater windows recorded the points of failure and the approximate amount of oil loss during the run. Video records and photographs were also taken during the test runs. After each test run was completed, the oil was skimmed to the north end of the tank and the next test run was begun. Excessive oil loss and boom stability failure determined the upper limit of tow speed.

$$y = \pm \frac{x^2}{36.77} + 0.76$$

$$0 \leq x \leq 13.39 \text{ m}$$

$$dy/dx = \pm \frac{x}{18.38}$$



x (m)	y (m)	dy/dx	θ (°)	Dist. along boom from main bridge (m)
0	± 0.76	0	0	
3.35	± 1.06	± 0.18	10.0	14.00
6.70	± 1.98	± 0.36	20.0	10.50
10.04	± 3.50	± 0.55	28.6	7.00
11.74	± 4.51	± 0.64	32.5	3.50
13.39	± 5.64	± 0.73	36.0	1.75
				0

Figure 14. Design of parabolic nozzle configuration.

SECTION 5

DISCUSSION OF RESULTS

The percent oil losses under and away from the boom were estimated by observers during the test and re-checked afterwards by using photographic and video records. The results are shown in Figures 15 through 18 and Tables 1 through 3. The lost oil was not recovered and measured. While the loss accounting may be inexact by 10 or 15 percent at most, the relative quantities of oil lost from one test to another are considered reliable.

Figures 15 and 16 are plots of tow speed vs. percent oil loss for 32° and 20° diversionary booms, respectively, and show the relative containment limits of the two boom configurations. The better performance of the 20° over the 32° configuration is quite apparent. Analysis of these results indicates that an additional investment in boom and securing lines to compensate for the reduced sweep width inherent in the lesser angles may be cost effective (see Appendix B), since it permits controlling oil that would otherwise be lost because of the current.

Figures 17 and 18 are plots of tow speed vs. percent oil loss for 20° "V" and nozzle configuration, respectively, and show the relatively greater effectiveness of the nozzle configuration at higher tow speeds. Its poorer results at the lower tow speeds are probably due to the increased angle of the leading edge of the booms.

Oil droplets passing beneath the skirt of a boom are not necessarily lost. They may be caught in the upwelling eddy and held against the back side of the boom. Oil held in this relatively quiet zone can be successfully diverted along the rear of the boom. The contribution of such diversion, shown in Figures 15 through 18, can be substantial. However at high tow speeds (>1 m/s), the oil droplets are smaller and entrain deeper into the water column. When this happens, there is less chance for the droplets to rise in time to reach the quiet zone.

The question whether a quantum increase in oil loss from in front of a diversionary boom occurs when the perpendicular component of current exceeds 0.51 m/s (a critical speed for oil shedding beneath a boom rigged perpendicular to the current (4)) can be investigated using the data obtained in these tests. As a boom is angled nearly parallel to the current, the normal (to the boom) component of the current speed decreases. The normal component of current to the boom is directly proportional to the sine of the rigging angle and that component reaches

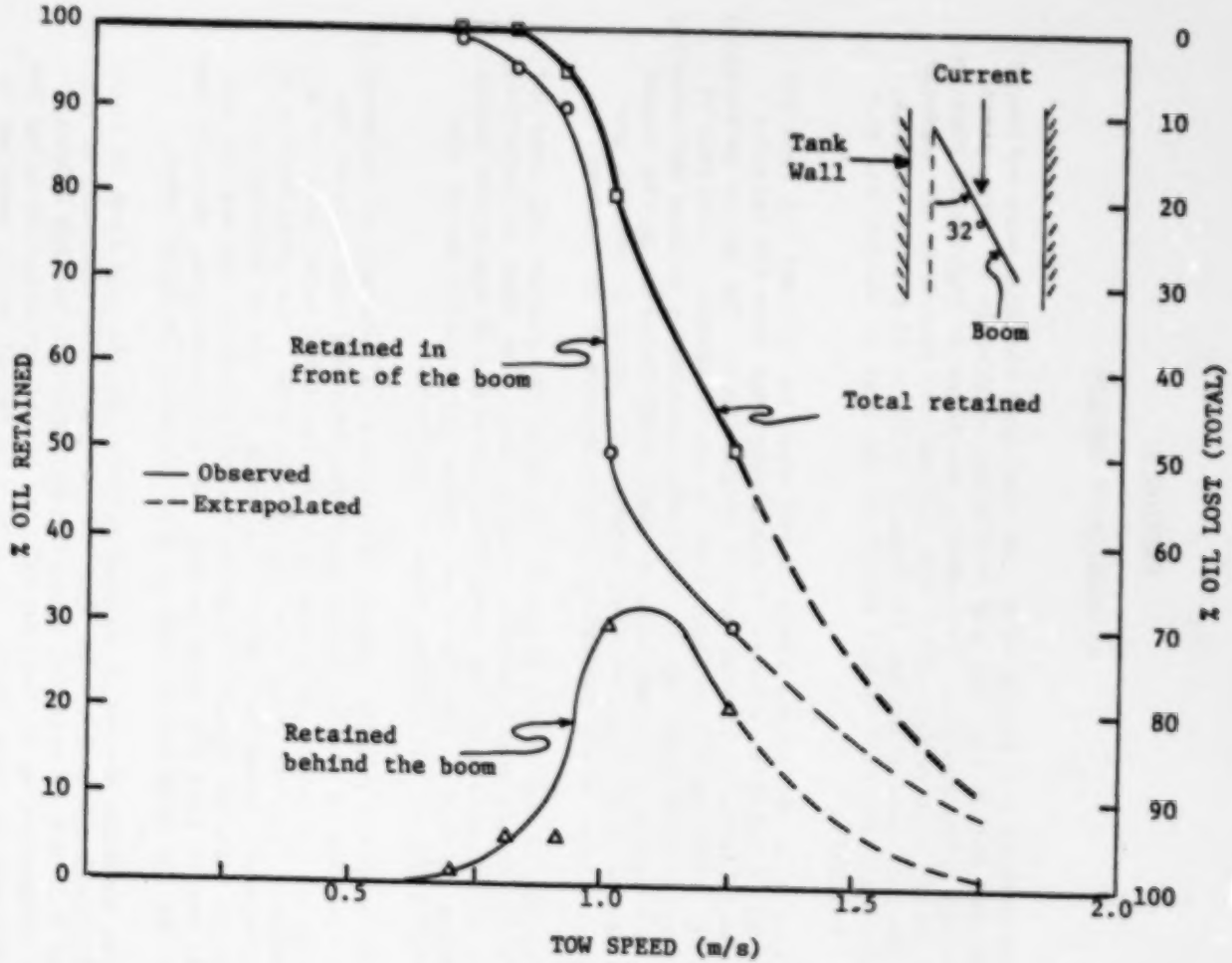


Figure 15. Performance of B.F. Goodrich 18 PFX boom (32° angle diversionary mode 28.5 m long).

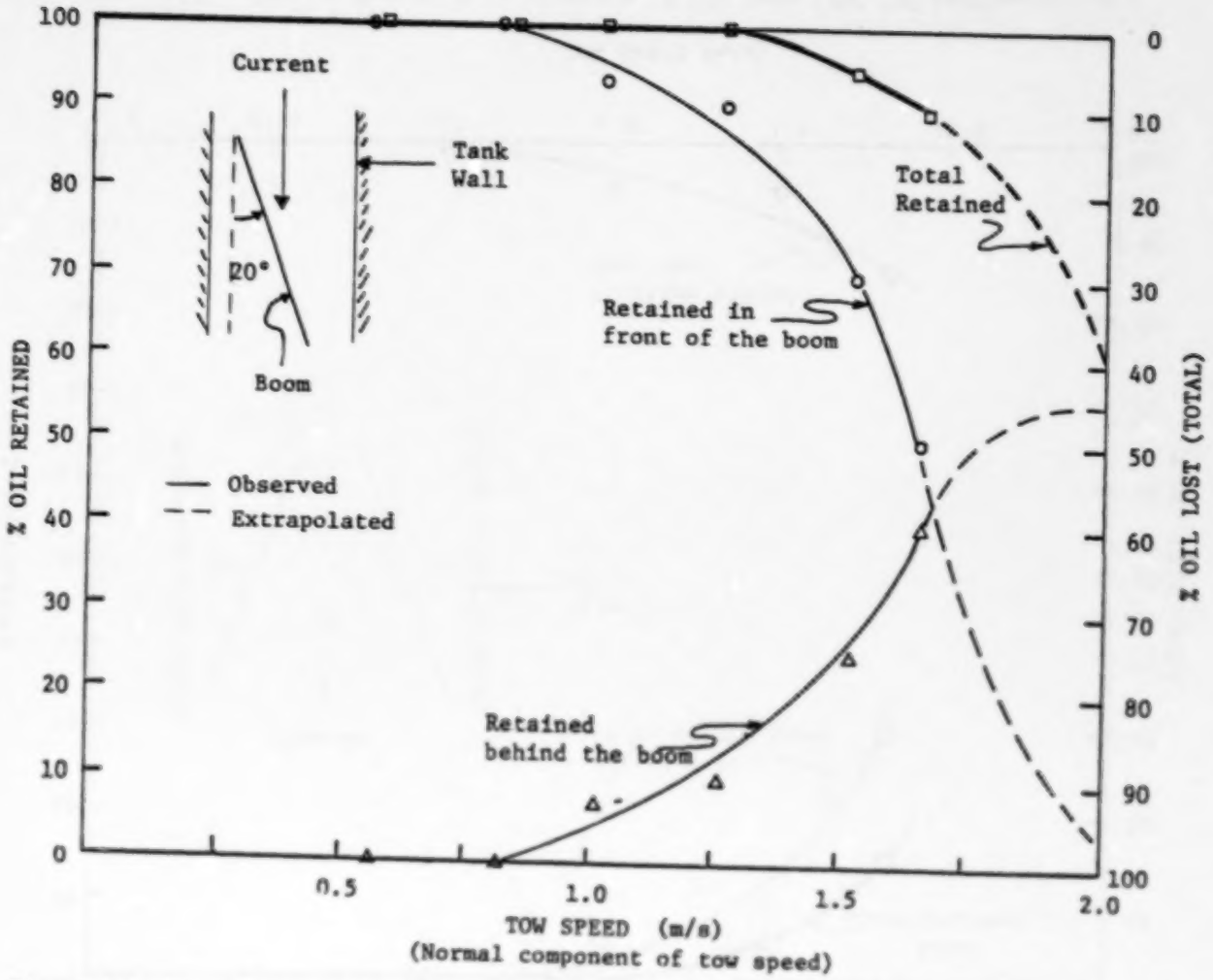


Figure 16. Performance of B.F. Goodrich 18 PFX boom (20° angle-diversionary mode 21.4 m long).

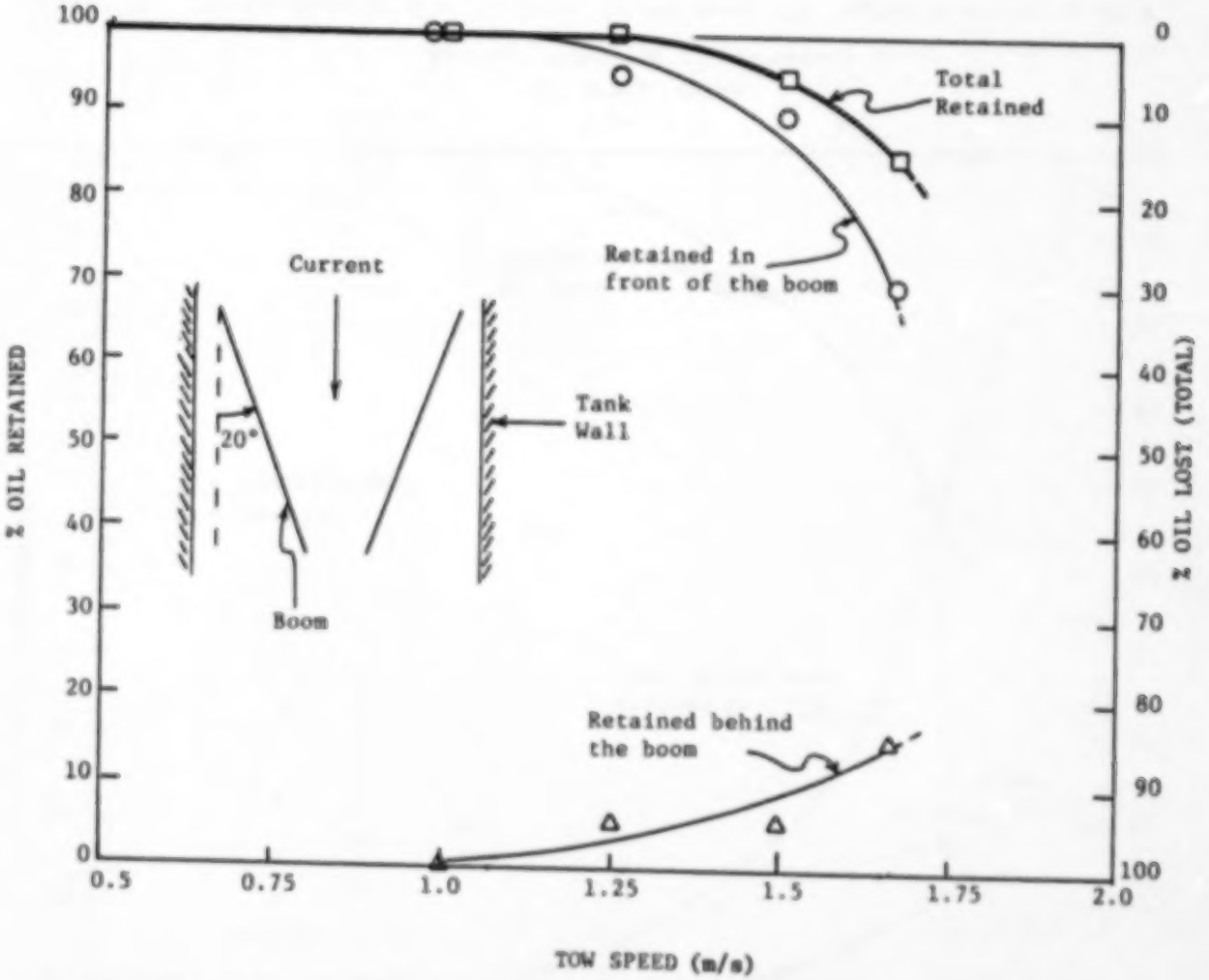


Figure 17. Performance of B.F. Goodrich 18 PFX boom (20° "V" configuration, 14.3 m on each side).

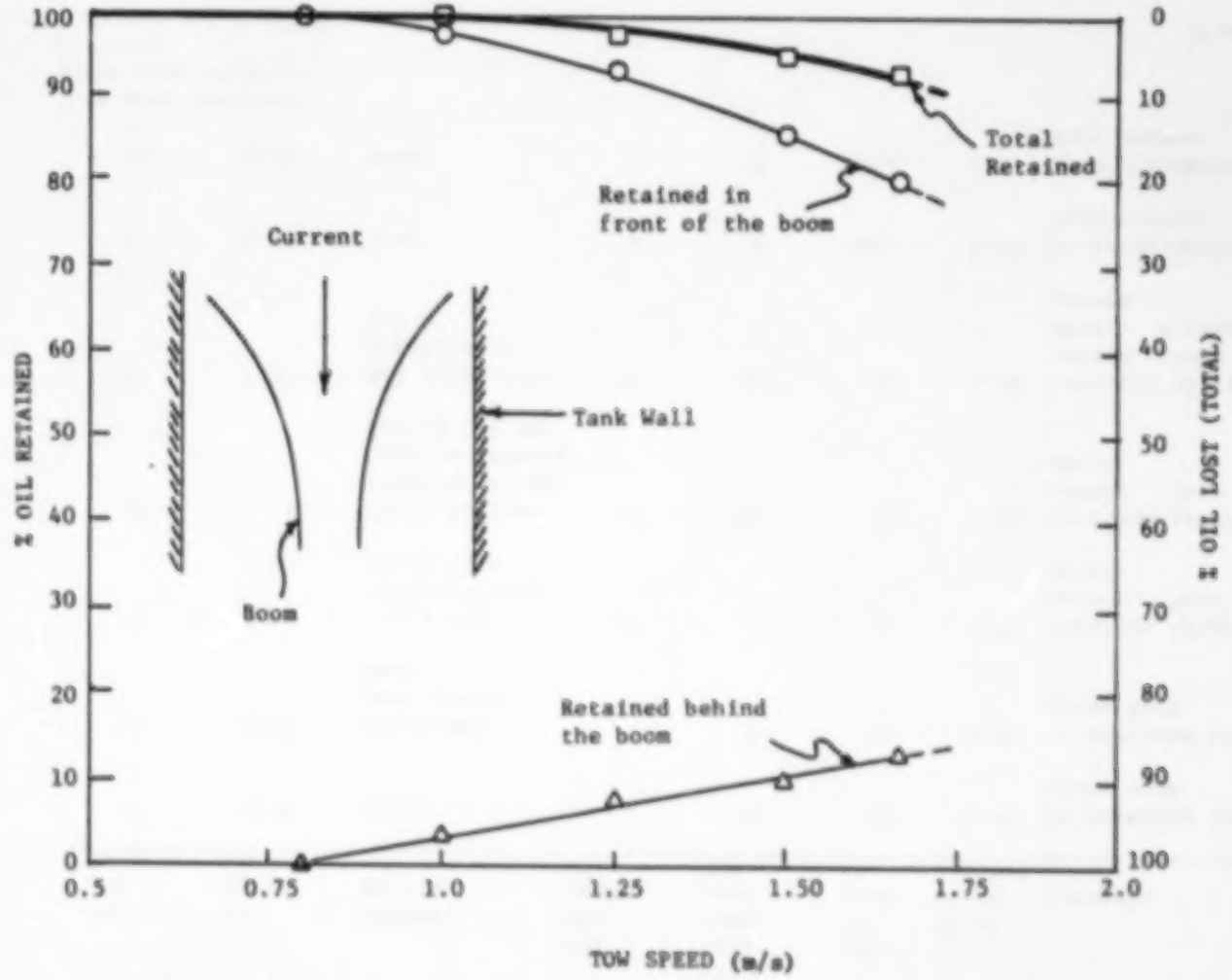


Figure 18. Performance of B.F. Goodrich 18 PFX boom (parabolic nozzle configuration, 14.3 m on each side).

TABLE 1. SINGLE DIVERSIONARY BOOM TEST RESULTS

Test no.	Boom ang. (deg.*)	Tow speed (m/s)	Failure points	Oil beneath (%)	Oil away from rear (%)	Type of loss **	Slick thick (mm)***	Comments
A-1	32	0.70	Cusps	1	0	Sh	1.94	No vortices formed along boom
A-2	32	0.81	Cusps and some along boom	5	0	Sh	1.99	No vortices formed along boom
A-3	32	0.91	Cusps and intermittently along boom	10	5	Sh	1.72	Vortices after boom passes. None along skirt.
A-4	32	1.01	Cusps predominantly; along boom increasing toward the end.	50	50	Sh	1.68	Vortices after boom passes. None along skirt.
A-5	32	1.26	All along boom starting at 3.5 m	70	50	Sh	1.48	Vortices after boom passes. None along skirt. Entrainment severe.
A-6	20	0.56	None	0	0	None	1.60	No entrainment after boom passes
A-7	20	0.81	None	0	0	None	1.14	No entrainment after boom passes

* 32 - four boom sections
20 - three boom sections
**Sh - Shedding
***Based upon a 9.1 m width

(Continued)

TABLE 1 (Continued)

Test no.	Boom ang. (deg.*)	Tow speed (m/s)	Failure points	Oil be-neath (%)	Oil away from rear (%)	Type of loss **	Slick thick (mm)***	Comments
A-8	20	1.01	Cusps	7	0	Sh	1.00	Small standing waves set up by parachute lines. Small entrainment and vortices after boom passes.
A-9	20	1.26	Cusps, amount increasing down the boom	10	0	Sh	1.10	Standing wave set up by line. Vortices and entrainment after boom
A-10	20	1.52	Starts at 5 m (first cusps at 7 m) sheds at all cusps	30	5	Sh	1.10	Standing wave with some entrainment because of lines. Entrainment and vortices after boom.
A-11	20	1.67	All along boom	50	10	Sh	1.10	Standing wave, severe entrainment. Planing failure in first section.
A-12	No lines	1.01	Begins at 16 m from front. Very severe	80	50	Sh	1.40	Severe entrainment and vortices following the boom. The boom was unstable at 1.26 m/s.

+Shedding (no vortices)

TABLE 2. DOUBLE DIVERSIONARY BOOM ("V") TESTS RESULTS

Test no.	Boom ang. (deg.*)	Tow speed (m/s)	Failure points	Oil beneath (%)	Oil away from rear (%)	Type of loss **	Slick thick (mm)***	Comments
B-1	20	0.56	None	0	0	None	1.12	No entrainment. No vortices.
B-2	20	0.81	None	0	0	None	1.15	Small vortices after boom.
B-3	20	1.01	None	0	0	None	1.15	Small vortices after boom.
B-4	20	1.26	At cusps	5	0	Sh	1.07	Slight entrainment and vortices follow boom.
B-5	20	1.52	All along boom	10	5	Sh	1.00	Entrainment begins at 6 m and continues along boom. Severe entrainment follows.
B-6	20	1.67	All along boom	30	15	Sh	1.07	Entrainment begins at 6 m and continues along boom. Severe entrainment follows.

*20 - two boom sections
**Sh - Shedding
***Based upon a 9.1 m width

TABLE 3. DOUBLE DIVERSIONARY (NOZZLE) BOOM TEST RESULTS

Test no.	Boom ang. (deg.*)	Tow speed (m/s)	Failure points	Oil beneath (%)	Oil away from rear (%)	Type of loss **	Slick thick (mm)***	Comments
C-1	Nozzle (2 sec. each side)	0.56	None	0	0	None	1.09	Spreader bar at rear causes standing waves
C-2	Nozzle	0.81	None	0	0	None	1.08	Turbulence on leading edge of nearest boom
C-3	Nozzle	1.01	Small losses at 2 m	3	0	Sh	1.08	Loss on nearest boom
C-4	Nozzle	1.26	Small losses at 4 m	10	3	Sh	1.10	Standing wave set up up by ropes
C-5	Nozzle	1.52	Losses start 3 m and continues to 7 m	15	5	Sh	1.09	Front end turbulence causes failure
C-6	Nozzle	1.67	Losses all along boom	20	7	Sh	1.09	Difficult to see if failure is consistent along the boom

(Continued)

TABLE 3 (Continued)

Test no.	Boom ang. (deg.*)	Tow speed (m/s)	Failure points	Oil beneath (%)	Oil away from rear (%)	Type of loss **	Slick thick (mm)***	Comments
C-7	Nozzle with belled exit	1.01	Start at 4 m losses along boom	10	3	Sh	1.08	Losses do not appear to be increasing along boom
C-8	Constricted nozzle exit belled	1.01	Losses begin at 3.5 m and continue down boom	10	3	Sh	1.08	Losses do not increase along the boom. Constricted throat increased boom angle slightly.

*Sh - Shedding
**Based on 9.1 m width

0.51 m/s against 32° and 20° booms at about 1 and 1.5 m/s, respectively. Figures 15 and 16 show oil loss as a function of the perpendicular (normal) component of tow speed and generally confirm the 0.51 m/s failure speed.

The nozzle configuration required the use of spreader bars to prevent the booms from collapsing into the center due to the venturi effect. The bars were placed at the nozzle exit and in the narrow section of the boom exit configurations. This would be another consideration when employing the nozzle configuration in the field. If the booms are allowed to collapse into each other, the oil could shed beneath them because of flow restriction.

Additional testing should be done to determine the effect of boom length on oil loss. Comparing the 20° diversionary and the 20° "V" configuration results, one can see that the extra boom length affected oil loss under the boom, but not away from the rear of the boom. The boom angle, not the boom length was the more critical parameter in these tests. At a tow speed of 1.02 m/s, the losses from the 32° diversionary were over five times those of the 20° diversionary boom.

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APPENDIX A

OHMSETT

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

The U.S. Environmental Protection Agency is operating an Oil and Hazardous Materials Simulated Environmental Test Tank (OHMSETT) located in Leonardo, New Jersey. This facility provides an environmentally safe place to conduct testing and development of devices and techniques for the control of oil and hazardous material spills.

The primary feature of the facility is a pile-supported, concrete tank, 203 metres long, 20 metres wide and 2.4 metres deep. The tank can be filled with fresh or salt water. The tank is spanned by a bridge capable of exerting a force up to 151 kilonewtons, which permits the towing of floating equipment at speeds up to 3 metres/second for at least 45 seconds. Slower speeds yield longer test runs. The towing bridge is equipped to lay oil or hazardous materials on the surface of the water several metres ahead of the device being tested, so that reproducible thicknesses and widths of the test fluids can be achieved with minimum interference by wind.

The principle systems of the tank include a wave generator and absorber beach, and a filter system. The wave generator and absorber beach have capabilities of producing regular waves up to 0.7 metre high and 28.0 metres long, as well as a series of reflecting, complex waves meant to simulate the water surface of a harbor or sea. The tank water is clarified by recirculation through a 0.13 cubic metre/second diatomaceous earth filter system in order to permit full use of a sophisticated underwater photography and video imagery system, and to remove the hydrocarbons that enter the tank water as a result of testing. The towing bridge has a built-in skimming board which can move oil onto the north end of the tank for cleanup and recycling.

When the tank must be emptied for maintenance purposes, the entire water volume of 9842 cubic metres is filtered and treated until it meets all applicable state and federal water quality standards before being discharged. Additional specialized treatment may be used whenever hazardous materials are used for tests. One such device is a trailer-mounted carbon treatment unit for removing organic materials from the water.

Testing at the facility is served from a 650 square metres building

adjacent to the tank. This building houses offices, a quality control laboratory (which is very important since test fluids and tank water are both recycled), a small machine shop, and an equipment preparation area.

This government-owned, contractor-operated facility is available for testing purposes on a cost-reimbursable basis. The operating contractor, Mason & Hanger-Silas Mason Co., Inc., provides a permanent staff of fourteen multi-disciplinary personnel. The U.S. Environmental Protection Agency provides expertise in the area of spill control technology, and overall project direction. An aerial view is given in Figure A-1.

For additional information, contact: OHMSETT Project Officer, U.S. Environmental Protection Agency, Research & Development, Edison, New Jersey 08817, 201-321-6631.

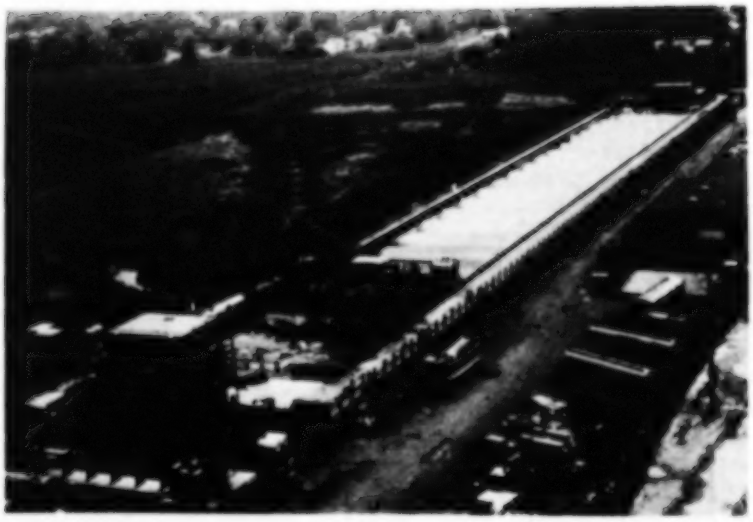

Figure A-1. Aerial view of OHMSETT.

APPENDIX B

This brief table illustrates the boom length necessary to cover various sweep widths using 20° and 32°-angle diversionary configurations. These figures do not include an opening at the apex.

TABLE B-1. DIVERSIONARY BOOM LENGTH vs. ANGLE COMPARISON

Sweep width (m)	20°-angle boom length	32°-angle boom length
25	73.1	47.2
50	146.2	94.4
75	219.3	141.6
100	292.4	188.8
200	584.8	377.6

Though the 20°-angle boom configuration requires 1.55 (inverse ratio of the sines) times as much boom as the 32°-angle configuration, the oil diversion performance is many times better. At 1.25 m/s, the 32°-angled boom loses half the oil it encounters, while the 20°-angled boom loses none.